SUSQUEHANNA RIVER BASIN COMMISSION
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MECHANICSBURG, PENNSYLVANIA 17055

PRELIMINARY INVESTIGATION REGARDING ESTABLISHMENT OF SWATARA CREEK WATERSHED LOCAL FLOOD WARNING SYSTEM

JANUARY 22, 1974

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PREFACE

This report was prepared as a first step toward implementation of Part II of the Recommendations for an Improved and Expanded Flood Forecasting System for the Susquehanna River Basin Commission on September 12, 1973. Part II calls for establishment of a Self-Help Flood Forecasting and Warning Program for small watersheds in the basin.

Swatara Creek Watershed was chosen from the suggested list in Part II of the recommendations for this first investigation study for several reasons including: a history of extensive flood damage within a number of damage centers, the variety and complexity of the hydrologic characteristics of these centers and their contributing watershed areas, the existing rainfall and stream gage records and past watershed investigations, and proximity of the watershed to the headquarters of the Susquehanna River Basin Commission, U.S. Weather Service and Pennsylvania DER.

TABLE OF CONTENTS

- I -

INTRODUCTION

Swatara Creek Watershed, located within the Susquehanna River Basin, has sustained significant flood damage along its waterways in the past. Because of its location, the watershed is receiving development pressures resulting in continuing construction on its flood plains and a corresponding increase in flood damage potential. No flood control projects presently exist or appear possible in the near future to reduce flood damages.

Establishment of a local flood warning system within Swatara Creek Watershed has been proposed to assist in reducing future flood damages. This report includes a preliminary investigation of Swatara Creek Watershed characteristics significant to the establishment of a flood warning system and a review of an already established local flood warning system in the Neshaminy Creek Watershed in southeast Pennsylvania.

- II -

GENERAL INFORMATION

Swatara Creek Watershed includes major portions of forty-one municipalities located in Dauphin, Lebanon, Berks and Schuylkill Counties in southcentral Pennsylvania. Swatara Creek Watershed encompasses 576 square miles and Swatara Creek reaches approximately 65 miles from its confluence with the Susquehanna River at Middletown Borough upstream past the Borough of Tremont in Schuylkill County.

The large tributaries of Swatara Creek include Little Swatara Creek, Quittapahilla Creek, Spring Creek, Manada Creek and Beaver Creek.

Swatara Creek Watershed contains approximately 156,000 permanent population according to 1970 census figures.

Municipalities having the largest population within the watershed are Middletown Borough, Derry Township, and Lower Paxton Township in Dauphin County; and Palmyra Borough, South

Lebanon Township, Lebanon City and North Lebanon Township in Lebanon County.

- III -

HISTORY OF FLOODING

A recording stream gage located at Harper Tavern, approximately 28 stream miles above the mouth of Swatara Creek, provides a record of repeated flooding since the year 1919. According to this stream gage data and other historic information, Swatara Creek flooded over its primary banks at Harper Tavern 129 times in the 42 years between 1919 and 1960.

Severe floods occurred within the watershed on June 1, 1889, August 24, 1933, and June 23, 1972. Swatara Creek reached a flood peak of 9.5 to 17.6 feet above the top of stream bank at Harper Tavern during these three events.

Moderate floods of 5 to 7 feet above the top of stream bank at Harper Tavern occurred in 1920, 1925, 1926, 1936, 1943, and 1951.

The remainder of Swatara Creek's flooding occurrences resulted in flood levels of less than 5 feet above the top of bank at Harper Tavern. Most of these floods occurred during the months of March, April and May.

USGS--Geological Survey "Water-Supply Paper 1889" provides the attached flood inundation map showing the extent of flooding along Swatara Creek in August 1933 from Pine Grove Borough to Middletown. This August 1933 flood reached a flood level of 374.2' above sea level or 9.5' above top of stream bank at Harper Tavern.

FLOOD DAMAGES JUNE 1972

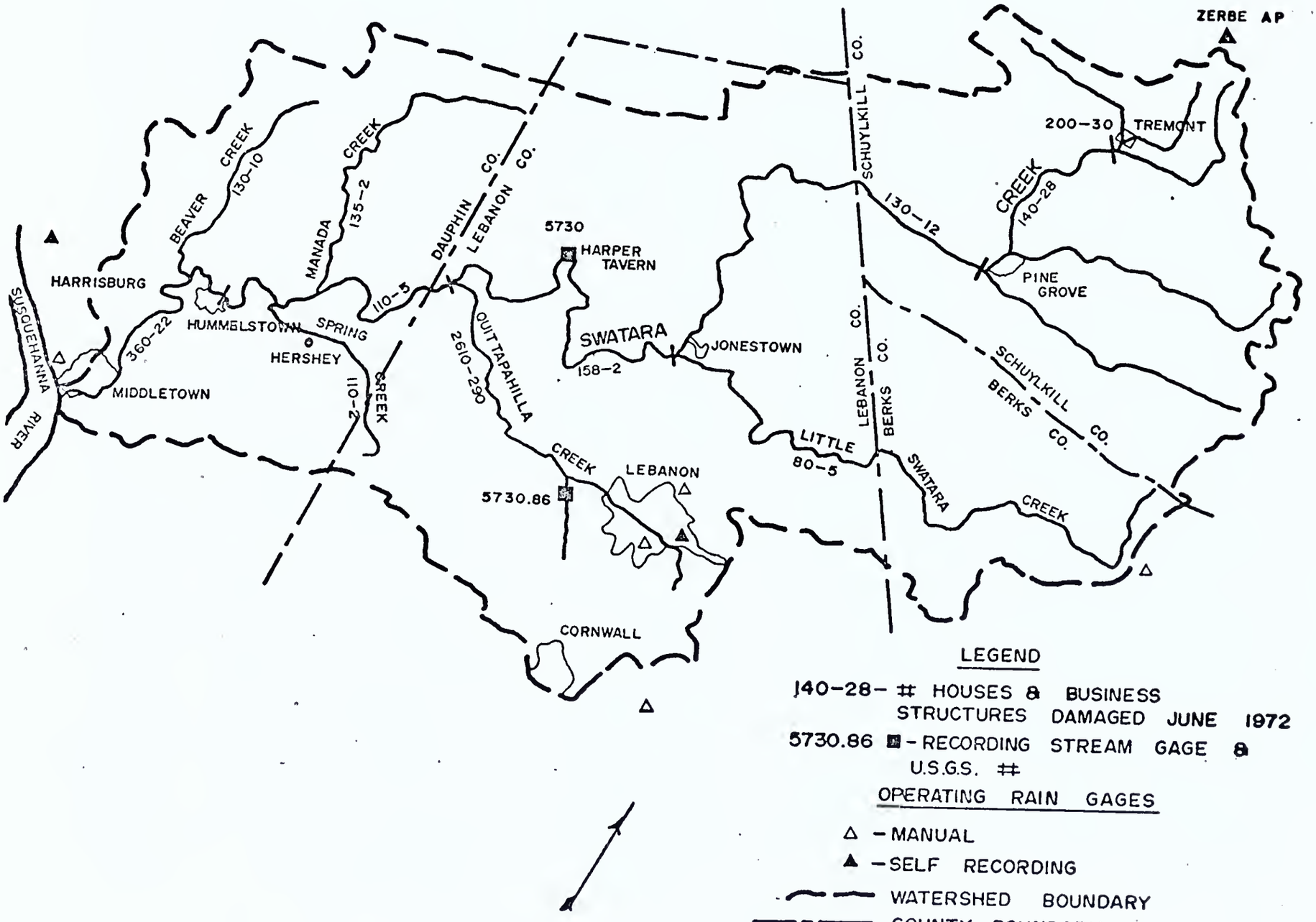
The June 1972 flood caused greater property damage than any previous flooding event in the Swatara Creek Watershed. It reached a flood peak of 380.4 feet at Harper Tavern, which was 15.9 feet above top of stream bank and 6.2' higher than the 1933 flood level.

According to surveys by municipal officials, approximately 4,200 residential structures and 410 commercial and industrial structures within the Swatara watershed suffered damage during this 1972 flood. Approximately 1,100 of the residential structures and 150 commercial and industrial structures damaged were located along the banks of Swatara Creek.

The majority of the flood damage within the watershed occurs along the sidestreams, with approximately 60% of the total watershed damage occurring along Quittapahilla Creek and its tributaries.

Other smaller concentrations of flood damage occurred along Spring, Beaver and Manada Creeks. These June 1972 flood damage property estimates are shown by general reaches on the Swatara Creek Watershed Map (Figure 1).

FIGURE 1 SWATARA CREEK WATERSHED MAP



LEGEND

140-28- # HOUSES & BUSINESS STRUCTURES DAMAGED JUNE 1972

5730.86 ■ - RECORDING STREAM GAGE & U.S.G.S. #

OPERATING RAIN GAGES

△ - MANUAL

▲ - SELF RECORDING

WATERSHED BOUNDARY

COUNTY BOUNDARY

FLOOD HYDROLOGIC CHARACTERISTICS ON SWATARA CREEK

The hydrologic characteristics of four historic flooding events within Swatara Creek Watershed were examined to determine possible advance warning times between time of significant rainfall accumulation and stream bankfull stage and peak flood stage at Harper Tavern. The four historic floods examined occurred on June 23, 1972; August 19, 1955; April 3, 1970 and February 3, 1970. The peak flood stages on Swatara Creek recorded at Harper Tavern for these floods were 23.9', 12.3', 12.9' and 9.7' respectively. All four floods exceeded the bankfull stage of 8.0' at Harper Tavern.

Rainfall data and flood stage information were compared to determine advance warning times possible for stream bank overflow warnings and for peak flood stage forecasts. Only limited information is available to make these examinations. This includes data from the recording stream gage located at Harper Tavern and from recording rain gages at Zerbe, Lebanon, Port Clinton, and Harrisburg.

It appears that during the June 1972 flood, this limited information would have allowed stream bank overflow warning two hours in advance for Harper Tavern, 8 hours for Hummelstown and 10 hours for Middletown. Flood stage forecasts could have been given about 9 hours in advance for Harper Tavern, 14 hours for Hummelstown and 16 hours for Middletown.

Characteristics of the other three floods varied widely, and consequently the possible advance warning times also varied. Advance times possible for stream bank overflow warnings varied from two to six hours for Harper Tavern and up to eleven and thirteen hours at Hummelstown and Middletown respectively. The least amount of warning time would have been possible for the February 1970 flood since the heaviest rainfall occurred in the lower portion of the watershed. Peak flood stage forecasts could have been provided 16 and 18 hours in advance for Hummelstown and Middletown respectively, in the August 1955 flood. Lesser advance warning time would have been possible in the April 1970 and February 1970 floods.

The examination of these floods is described in detail in D. R. Jackson's report, "Hydrologic Evaluation of Feasibility

Swatara Creek Self-Help Warning System", November 20, 1973, which is attached as Appendix A.

Examination of the four flooding events points out that the limited amount of data available allows flood warnings and forecasts early enough to be of value in flood damage reduction on the lower portion of Swatara Creek. It seems reasonable to assume that additional data to be collected as part of a local flood warning system would allow significant advance warning times for a greater length of stream and allow more accurate forecasts. Whether flood warnings and forecasts of value can be provided to upstream and sidestream flood damage centers cannot be determined until a warning system is designed and tested.

- VI -

FLOOD PREVENTION PROJECTS IN SWATARA WATERSHED

No flood prevention projects currently exist and none are scheduled for construction in the near future in the Swatara Creek Watershed. Several flood control studies are underway and a State project has been proposed in the Swatara Creek Watershed.

A State park and dam project has been proposed on Swatara Creek at Swatara Gap. According to information from Pennsylvania Department of Environmental Resources personnel, the preliminary dam proposal includes provisions for water supply and recreational uses but little flood control. The effects of this structure on flood hazards will probably be negligible. Scheduling of further planning and design is reported to be indefinite.

U.S. Soil Conservation Service has completed a feasibility study of the Quittapahilla Creek for the P.L. 566 Flood Control Program. This study shows the possibility of five dams to provide flood protection on the Quittapahilla Creek downstream as

far as Annville Township. At least ten years time could be required to install any structures approved for this project area under this program. The City of Lebanon has initiated a study to determine the feasibility of a local flood control project along Quittapahilla Creek within the City of Lebanon.

It would appear from this information that no significant flood damage reduction measures can be anticipated in the near future within the Swatara Creek Watershed and any present needs for a flood warning system will continue into the foreseeable future.

- VII -

HYDROLOGIC DATA COLLECTION WITHIN SWATARA CREEK WATERSHED

A number of hydrologic data collection stations are currently being operated within or near the Swatara Creek Watershed.

U.S. Geological Survey currently maintains and operates two self-recording stream gages within the watershed. These are located on Swatara Creek at Harper Tavern and on Beck Creek (a tributary of Quittapahilla Creek) near Cleona Borough.

U.S. Weather Service maintains and operates a number of rain gaging stations within or near Swatara Creek Watershed. Recording rain gages are located within the watershed at Lebanon City and Zerbe AP. Non-recording rain gages within the watershed are located at: Pine Grove, Lebanon and Middletown. Recording rain gaging stations located outside but within ten miles of the watershed boundary include: Port Clinton, Tower City, Landisville, Lititz and Harrisburg AP. Non-recording rain gaging stations located outside but within ten miles of the watershed boundary include: York Haven, Mt. Gretna, Myerstown, Strausstown, Berne, Pottsville and Gordon.

The locations of those stations located within or immediately adjacent to the watershed are shown on Figure 1.

These data collection stations presently in operation could be utilized in a local flood warning system.

- VIII -

REVIEW OF NESHAMINY VALLEY FLOOD WARNING SYSTEM

The Neshaminy Valley local flood warning system was established in 1957 and has been in operation since that time. This system has been proposed as a model to be investigated for adaptation to several upstream watersheds within the Susquehanna River Basin.

Neshaminy Creek watershed is located in southeastern Pennsylvania in Bucks and Montgomery Counties. The watershed drainage is 232 square miles and contains a number of heavily populated municipalities. Neshaminy Creek is roughly 46 miles in length and drains directly into the Delaware River.

The Neshaminy Valley local flood warning system was established as a result of the heavy damage during the floods of August 1955. The system was sponsored and organized by the Neshaminy Valley Watershed Association, under the supervision of the U. S. Weather Bureau, in cooperation with the Federal-State Flood Forecasting Service. The Watershed Association has operated the data collection, evaluation and prediction, and warning dissemination phases of the system entirely through volunteer assistance. The phase of the warning process involving rescue and damage prevention actions taken as a result of the warnings was considered the responsibility of police, Red Cross and Civil Defense. The Association did, however, survey flood damages and prepare reports on flood damage and system effectiveness as follow-up activities after a flood.

In actual operation, ten rain gaging stations located throughout the watershed and four stream gages were manned by volunteer observers on a continuous basis. Whenever any rain gaging station recorded 1 inch or more of rainfall in any 24-hour period or less, a report was made to the Flood Warning Coordinator, who was responsible for receiving data, preparing flood warnings and forecasts, and disseminating this infor-

mation to responsible persons and agencies. The Coordinator was assisted in preparation of forecasts by technical information provided by the U. S. Weather Service, U. S. Geological Survey and Pennsylvania DER. The U. S. Weather Service Station at Philadelphia Airport was available for additional guidance and assistance. The warnings and forecasts were disseminated in the form of expected degree of flood severity; as minor, moderate, or severe flood forecasts. These three classifications were correlated to predicted flood crest elevations at a recording stream gage on the lower Neshaminy. To allow proper use of these warnings along all major stream sections, the Association calculated Flood crest travel times and various frequency flood levels along all major stream lengths and prepared maps showing areas which would be inundated in minor, moderate, and severe flooding events. This material was provided and explained to all persons and agencies receiving the flood warnings. Copies of all forecasts issued were telephoned to the U. S. Weather Airport Station for their information.

The system was operated and maintained by the Association members and other interested persons on an entirely volunteer basis from 1957 until recently when operational difficulties were experienced. At this point in time the Natural Resources Division of the Bucks County Planning Commission assumed responsibility for the warning system. The difficulties of the volunteer system in recent years is reported to have resulted from the loss of several deeply interested and dedicated Association members who had been largely responsible for its operation.

Under the responsibility of Natural Resources Division the system is changing to operation by paid agency employes. Employes of the Natural Resources Division carry out the Flood Warning Coordinator's role, rain gaging stations are being transferred to municipal police stations, and stream gages are being manned by local police and other paid municipal personnel. The Coordinator maintains the same responsibilities, and the types of forecasts prepared remain the same. The warning dissemination process remains essentially the same, utilizing county police and fire radio networks and Civil Defense warning systems. However, the Coordinator is now located with the radio network communications center and Civil Defense Headquarters, and telephone communication to the center and headquarters is no longer necessary.

SUMMARY OBSERVATIONS AND CONCLUSIONS

Swatara Creek Watershed has a history of frequent flooding events and considerable flood damage. Flood control measures are not presently being actively applied within the watershed, and similar flooding events in the future will result in increased damages.

The last severe flooding event caused flood damages along the entire lengths of the main stream and major tributaries, but damage centers are located on upper and lower portions of Swatara Creek, on Spring Creek and on Quittapahilla Creek. An effective local flood warning system for the watershed must provide useful flood forecasts or warnings for the upstream and sidestream damage centers; especially Quittapahilla Creek.

Swatara Creek Watershed covers major portions of 41 municipalities within four counties. County-wide police and fire communication systems presently exist and county-wide coordination is possible through existing agencies and organizations. Inter-county communication and coordination systems are not available within the watershed. It would appear that operation of a watershed-wide local flood warning system would require a county level or multi-county regional level agency or organization. A second alternative to this watershed-wide system would be several smaller local systems, each designed to serve an individual flood damage center.

Information received on the Neshaminy Valley local flood warning system indicates that a successful volunteer manned system requires a central core of deeply interested and capable individuals, with sufficient time available to operate and maintain such a system on a continuous long-term basis. Considering this requirement, any local flood warning system proposed by SRBC should be designed for operation and maintenance through paid personnel of State, regional, county and municipal agencies. Creating or recruiting an agency to assume responsibility for the Flood Warning Coordinator's role as defined in the Neshaminy system will probably be the most difficult problem in establishing any local flood warning system.

A number of alternatives not included within the Neshaminy system should be considered during the design of a proposed local

flood warning system for Swatara Creek Watershed or other upstream watersheds within the basin. Automatic equipment including recording rain and stream gages, automatic warning device attachments to rain and stream gages, and automatic public alarm systems should be investigated for practicability and availability. The value of utilizing rainfall data from gaging stations located outside the watershed for advance warnings should be investigated and considered. The possibilities of utilizing one agency or organization to operate more than one local flood warning system should be considered.

From this preliminary investigation several conclusions can be drawn as follows:

1) The need exists for a flood warning system within the watershed.

2) Available data indicates that flood forecasting and warning is definitely feasible on Swatara Creek as far upstream as Swatara Gap.

3) Flood warning or forecasting is necessary in upstream and sidestream areas, but providing sufficient warning times to these areas may be difficult.

4) Providing sufficient flood forecasting times to the Lebanon City area, located on the headwaters of Quittapahilla Creek, appears to be almost impossible. This area which sustained heavy damages during the June 1972 flood should receive high priority in consideration for a flood control project.

5) The Neshaminy Valley local flood warning system has been of value in reducing flood damages and in reducing panic and anxiety of property owners threatened during minor and severe flood events.

6) Organizing and establishing a system throughout Swatara Creek Watershed will be more difficult than on the Neshaminy because of the greater size and complexity of the Swatara Watershed, and because of less visible interest in a warning system from within the Swatara Watershed.

7) A successfully operating warning system in any watershed will be primarily dependent upon the interest of local municipalities, organizations and residents and their willingness to participate in the operation of the system.

IMPLEMENTATION RECOMMENDATIONS

Establishing a successful operating local flood warning system in Swatara Creek Watershed will require extensive further effort by SRBC. This will include establishing local responsibility, flood plain studies, detailed meteorological and hydrological investigation, forecasting system design, system operation initiation and follow-up.

Following is a brief description of the tasks required to establish the system:

1) Establish local responsibility for operation and maintenance of the local flood warning system. This involves contacting and meeting with local governmental agencies, organizations and individuals to assess overall and individual interest in the proposed system; recruiting qualified, interested local organization; and adjusting final system design to capabilities of the local operational organization.

2) Secure cooperation and assistance from appropriate State and Federal agencies, including U.S. Weather Service, U.S. Geological Survey, and Pennsylvania DER to establish and operate a local flood warning system.

3) Design a flood warning system. This task involves collecting and analyzing available rainfall and stream gage records, selecting gaging and warning equipment, selecting sites for instrument stations, estimating costs for establishing the system, and preparing technical guides for flood forecasting.

4) Conduct a hydrologic study of the major flood plains of the watershed. This study would include preparing topographic maps of the flood plains, computing the 10, 50 and 100 year frequency flood levels, and determining flood crest travel times.

5) Initiate operation of the local flood warning system. This task includes installing gages and warning devices, training observers and forecasters, instructing warning and rescue agencies in use of forecasts and flooding information, informing

the public of the system's structure, operation and benefits of the system, and testing operating procedure.

6) Maintain and evaluate system operation. Continued evaluation of the system's effectiveness will be necessary. This evaluation will determine if and when further study, revision of technical guides, adjustment of the system design or additional personnel training will be necessary.

Of these tasks, establishing local responsibility, securing Federal and State agency cooperation and assistance, conducting watershed studies and designing the system can be carried out concurrently with coordination of work scheduling. The time period required to complete these tasks can range from six to twelve months depending upon the availability of SRBC staff personnel, the amount of assistance available from the Federal and State agencies and the interest of local agencies.

Upon completion of these tasks, operation of the system can be initiated. Achieving functional operation of the system could require as much as 12 months time depending upon the type of equipment selected and the availability of observers and observation stations. Evaluating and adjusting the system should be a continuous task throughout the existence of the local flood warning system.

APPENDIX A

HYDROLOGIC EVALUATION OF FEASIBILITY SWATARA CREEK SELF-HELF WARNING SYSTEM

In this hydrologic evaluation, four history floods were examined to determine whether warnings could be prepared for the main stem of Swatara Creek below Swatara Gap. The four historic floods were June 23, 1972, August 19, 1955, April 3, 1970 and February 3, 1970. The peak stages at the Harper's Tavern gage are shown in Table 1.

Table 1

Peak Stages of Selected Historic Floods at Harper Tavern

Date	Stage
June 1972	23.9
August 1955	12.3
April 1970	12.9
February 1970	9.7

All four floods exceeded the bankful stage of 8.0 feet at Harper Tavern. The June 1972 flood is the flood of record at this location. The continuous record goes back to 1919 but historic data is available as far back as 1889. These four floods were chosen in order to obtain a range of flood conditions.

For the latter three floods, the stage hydrograph at Harper Tavern and the rainfall mass curves for Port Clinton, Lebanon and Harrisburg were plotted on the same sheet of paper. These plots were examined to obtain an estimate of the lead time prior to bankfull and peak that would be possible for each storm. For the June 1972 flood, the following data, tabulated by H. W. Miller was studied.

Table 1
RAINFALL DATA - JUNE 1972 TROPICAL STORM

Item	Harrisburg	Landisville	Sunbury	Tamaqua
Start of Significant Rain	11:00 a.m., Wednesday	2:00 p.m., Wednesday	3:00 p.m., Wednesday	5:00 p.m., Wednesday
2"	4:00 p.m., Wednesday	5:00 a.m., Thursday	11:00 p.m., Wednesday	8:00 p.m., Wednesday
4"	11:00 p.m., Wednesday	8:00 a.m., Thursday	1:00 a.m., Thursday	Noon Thursday
6"	1:00 a.m., Thursday	Noon Thursday	4:00 a.m., Thursday	2:00 p.m., Thursday
8"	8:00 a.m., Thursday	--	2:00 p.m., Thursday	--

Flood stage at Hummelstown and Union Deposit - Thursday at 4:00 a.m.

In addition to examining the plots, the travel time from Harper Tavern to Hummelstown and to Middletown was estimated using the kinematic wave velocity (Sedden's Law) given by:

$$c = \frac{\Delta Q}{\Delta A}$$

The change in discharge and change in area was obtained from the rating curve and the measured cross section at the gage, respectively, for assumed flood elevations. The wave velocity was obtained by dividing change in discharge by the corresponding change in area. The wave velocity was divided into the stream distance from the gage to Hummelstown and Middletown respectively. These distances are 117,000 feet (22.6 miles) and 146,000 feet (27.6 miles) respectively. Some representative travel times so obtained are shown in Table 2.

Table 2

REPRESENTATIVE TRAVEL TIMES FROM HARPER TAVERN

Stage Feet	Travel Time (Hours) Hummelstown	Middletown
5.00	8.	10.
8.0	8.	10.
9.0	7.	9.
10.0	7.	8.
11.0	6.	8.

The accuracy of this method of obtaining travel times is uncertain, and the values shown should be verified by further study. As a matter of judgement, they should be considered to be good within $\pm$ 1 hour.

It is very difficult to determine the amount of warning that could be given in an actual flood event, because we have the benefit of having all the data available, while the forecaster under an actual flood situation has only limited data. Also, the reliability of the flood forecasting procedure is impossible to assess without having an actual procedure established. Ideally, a flood forecasting procedure should be developed, and the lead time determined by simulating the actual event. In the absence of such a procedure, we can only estimate the lead time that would be available.

For the June 1972 flood, it appears that there was 2" of rain at Harrisburg by 4:00 p.m., June 21 and at Tamaqua by 8:00 p.m. With hard rain continuing, it should have been possible to issue, at the least, a warning of moderate flooding on the Swatara by around 8:00 or 9:00 p.m. on Wednesday, June 21. It may have also been possible to issue a preliminary stage forecast for Harper Tavern at the same time, although such a forecast would have been too low. However, this would have provided 2 hours advance warning that the Swatara would overflow its banks at Harper Tavern. With the travel times estimated previously, this should have given about 8 hours warning to Hummelstown and 10 hours warning at Middletown. This is confirmed by the statement above that flood stage was reached at Hummelstown at about 4:00 a.m. on June 22. The peak stage at Harper Tavern occurred at about midnight on June 22. Rainfall mass curve plots for Reading and Lancaster show

that the heavy rain ended at about 3:00 p.m. At that time, the accumulated rain at Harrisburg was about 13.5 inches, which was almost 90% of the total. Thus a stage forecast made at that time should be accurate within ± 0.5 feet and the lead time would be about 9 hours at Harper Tavern, about 14 hours at Hummelstown and about 16 hours at Middletown. The estimate for Middletown may not be quite right because of the spatial distribution of rainfall, which may have caused Swatara Creek to peak earlier at Middletown than at Harper Tavern. Also, by this time, the Susquehanna was already well above flood stage at Harrisburg.

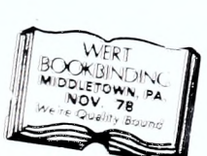
For the flood of August 19, 1955, the rainfall was greatest in the upper part of the watershed. Swatara Creek overflowed its banks at Harper Tavern at about 3:00 p.m. on August 18. In this case forecasting bankfull stage at Harper Tavern appears to be difficult with the data available. Probably a moderate flood warning should have been issued about 12 noon, thus providing 3 hours warning time at Harper Tavern, and 11 hours and 13 hours warning at Hummelstown and Middletown, respectively. The peak stage forecast is somewhat easier, since the rain ended at all stations by midnight on August 18, and Swatara Creek crested at about 9:00 a.m. at Harpers Tavern. Thus it should have been possible to forecast the peak stage with reasonable accuracy at least 9 hours ahead for Harper Tavern, and 16 and 18 hours ahead for Hummelstown and Middletown respectively.

For the April 1970 flood, a warning of moderate flooding could have been issued at least 3 hours before Swatara Creek went out of bank at Harper Tavern. The warning might have been issued as much as 6 hours ahead, on the basis of the gage height and rainfall to that time. The final stage could probably have been forecast at about 12 noon on April 2, about 12 hours warning could have been provided for Harper Tavern.

For the February 3, 1970 flood, Swatara Creek overflowed its bank at Harper Tavern at about 10:30 a.m. on February 3. In this case, the warning of out-of-bank flooding could not have been issued before 5:00 a.m. and possibly not until 9:00 a.m. The peak was reached at about 2:00 p.m., and it is questionable whether much lead time could have been given. Also, since the heaviest rainfall occurred at Harrisburg, it is likely that Swatara Creek crested at Hummelstown and Middletown earlier than would be expected based on the estimated travel time. Thus, for this event, the warning system may not have provided as much lead time as for the other events.

In summary, it is the writer's opinion that a self-help warning system could be developed that would provide a substantial lead time for Hummelstown and Middletown. Some warning would also be possible in most cases for the main stem of Swatara Creek as far upstream as Swatara Gap. It may be possible to forecast for off-main-stem locations in a general way, but for some areas, most notably Lebanon, some sort of warning bell would seem advisable.

Whether the self-help system will prevent sufficient damages to pay for itself is even more difficult to determine without additional data. In particular it is necessary to determine which structures are in the flood prone area, and the dollar damages which could be prevented by the self-help system.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